CHAPTER 17

17.1 GOVERNMENT PROGRAMS

The New Zealand government's state policy for energy is to ensure the continuing availability of energy services at the lowest cost to the economy as a whole, consistent with sustainable development. Direct government funding is not available for the development or assistance of renewable energy. However, the Energy Efficiency and Conservation Authority (EECA) is funded by the government for the purpose of promoting the uptake of energy efficiency and conservation and renewable energy. With respect to renewable energy, EECA's primary function is to disseminate information on potential energy sources and their application.

EECA, with support from the New Zealand Wind Energy Association (NZWEA), has applied to the Inland Revenue Department for a more accurate tax depreciation rate for wind turbine generators which, if granted, will improve wind power plant economics.

17.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

The total grid-connected wind turbine capacity in New Zealand remains at just under 4 MW. The installed wind turbines include seven Enercon E40 turbines (the 3.5-MW Hau Nui wind farm), a Vestas V27 owned by the Electricity Corporation of New Zealand (ECNZ), and various small turbines owned by other parties.

New Zealand's first commercial wind farm (Hau Niu) completed its first year of operation in June 1997. The predicted annual energy production was 12.8 GWh, based on an average wind speed of 9.7 m/s. The owners, the local power company, Wairarapa Electricity, recorded an actual energy production of 12.5 GWh for the year to June 1997. The latest figures indicate a 10% increase on predicted values. with 8.9 GWh of energy being produced during the 7 months from July 1997 to January 1998 is 50%. Availabilities of the Hau Nui turbines to date have been high, achieving an average greater than 99%. Research has indicated that, although the strong trade winds ("roaring forties") prevailing in New Zealand give large generation, they can also cause production losses due to frequent shutdowns in high winds. The amount of energy lost depends on the type of control system employed by the wind turbine. The Hau Nui machines have modified operation at the high wind speed end of the power curve to reduce the hysterisis losses due to high wind speed shutdowns.

The ECNZ V27 wind turbine in Wellington has produced 911 MWh in the year to June 1997, giving a capacity factor of 16%. The availability was just over 98%.

Commercial interest in wind power is steadily increasing as it becomes competitive in the fully deregulated market. CentralPower, a power company in the central North Island, is now developing a 32-MW wind farm. This wind farm, to be built by Vestas and DesignPower NZ Ltd, will be the biggest wind farm in the Southern Hemisphere.

ECNZ is undertaking public consultation for a proposed 30- to 40-MW wind farm at Makara near Wellington.

Power companies and developers continue to monitor and assess various potential wind farm sites around New Zealand. Sites with a total installed capacity of up to 600 MW are currently being investigated. High annual average wind speeds of approximately 10 m/s are expected to make wind farms on these sites economically attractive.

In New Zealand, the majority of electricity is produced by hydro-power stations with an installed capacity of approximately 4,800 MW. The remainder of the nation's electricity is produced by fossil fuel and geothermal power stations, which together have an installed capacity of approximately 2,600 MW.

17.3 MANUFACTURING INDUSTRY

A 7-m rotor diameter prototype diffuser augmented wind turbine, the "Vortec 7", has been developed and constructed (March 1997). The prototype turbine has been scaled up 15 times from the original Grumman Aerospace wind tunnel model, which was the subject of a test program completed in 1982. The Vortec 7 is being used for testing and verifying CFD modeling to improve and optimize the diffuser topography and technology.

A prototype vertical-axis wind turbine is being developed with the aim of producing economically viable medium-to-large scale machines. The patented design allows high efficiency and large sizes (multi-megawatt) without excessive stress on the blades. Wind turbines of 100 kW to 2 MW are expected in the next 3 years, followed by 3 to 5-MW machines. The New Zealand company, Wind Torque Limited, is planning to begin production of a two-bladed, teetering hub turbine which incorporates a "Torque Limiting Gearbox" to allow variable-speed operation.

Local industry has the expertise to manufacture turbine towers, as was proven with the construction of seven tubular towers for the Hau Nui wind power plant. Local construction and manufacturing industry content for CentralPower's 32 MW wind farm will include the lattice towers, foundations, and the electricity reticulation and distribution systems. The local fiberglass industry has expressed interest in manufacturing wind turbine blades. They already have considerable experience in advanced technology and industrial applications, as well as in New Zealand's highly successful boat building industry.

17.4 ECONOMICS

New Zealand has a deregulated wholesale electricity market in which wind power competes directly with other forms of generation without subsidies or incentives. The overall average wholesale power price for 1997 was approximately 4.5 NZ cents / kWh, with some large spot price variations occurring in the newly implemented electricity market. Extra charges are applied to the wholesale price for transmission of the electricity. The open electricity market therefore provides a natural incentive to produce electricity close to load sources which can allow electricity transmission charges to be reduced or avoided.

Wind power plants constructed at the best sites in New Zealand are expected to produce electricity at a cost of between 5.5 and 7.5 NZ cents / kWh, given current wind turbine prices.

17.5 MARKET DEVELOPMENT

Research is continuing on understanding the performance of wind turbines in New Zealand's high wind speed environment. The commissioning of New Zealand's first wind farm has extended the operational experience of wind turbines in this environment.

NZWEA was formed with members from all parts of the wind power industry. The NZWEA mission statement is "To promote the uptake of New Zealand's abundant wind resource as a reliable, sustainable and clean energy source." In June 1997 EECA and NZWEA organized the inaugural NZWEA Annual General Meeting and Conference. In addition, a wind power symposium was incorporated into the IEA Wind R&D Executive

Committee's meeting in New Zealand in November 1997.

17.6 GOVERNMENT-SPONSORED R, D&D PROGRAMS

The New Zealand government is funding wind power related research work through its contestable Public Good Science Fund (PGSF). Testing of the Vortec 7 prototype wind turbine is partially funded from this fund. Another current project, investigating the potential loss of a significant amount of energy due to the hysterisis effect of high wind speed shut downs if wind turbines do not include appropriate control algorithms, is being undertaken by DesignPower New Zealand Ltd. Funding from the PGSF for wind energy related research for the year 1997 was approximately NZ $230,000, and is expected to increase in 1998, with several proposals for funding being made for wind power related research.

CHAPTER 18

18.1. GOVERNMENT PROGRAMS

18.1.1 Aims and Objectives

Government policy on the energy sector is that Norway, in a normal year, shall be self-supporting in its electricity supply, based on renewable energy sources (hydro-power and new renewable sources of energy). Because the availability of new hydro-power schemes is limited, it will be necessary to look into alternative solutions in order to cover the power demand in the future.

18.1.2 Strategy

Commercial implementation of new energy projects is the general strategy to cover the power demand in a deregulated Norwegian electricity market. Norway has traditionally had some surplus power, but foresees a more confined power balance in the coming years. This implies that it is essential to develop new energy technologies in such a way that these may be real alternatives to meet the future power demand. To meet this demand the government wishes to direct more efforts towards the exploitation of new renewable sources of energy. The budget amounts for government support of activities within these fields (including wind energy) are, therefore, supposed to be increased in the coming years, however, no specific targets have been announced for this support so far.

18.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

18.2.1 Installed Wind Capacity

The national target in a former demonstration program was to have wind turbines with a nominal capacity of 3-4 MW connected to the grid system by the end of 1993. At present, 12 wind turbines (3.9 MW, all of Danish manufacture) are installed along the Norwegian west coast, as listed in Table 18.1. There have been no installations or removals of wind turbines during 1997.

Table 18.1 Wind Turbines and Output.

WIND TURBINE PROJECTS	RATED POWER (kW)	YEAR OF COMMIS-SIONING	PRODUCTION IN 1997 (GWh)	TOTAL OUTPUT OVER ALL YEARS (GWh)
Frøya	1 x 55	1986	0.143	1.485
Frøya	1 x 400	1989	0.993	6.286
Vallersund	1 x 75	1987	0.193	1.910
Kleppe	1 x 55	1988	0.041	0.422
Smøla	1 x 300	1989	0.767	4.974
Andøya	1 x 400	1991	1.023	6.133
Vesterålen	1 x 400	1991	1.117	7.070
Vikna	3 x 400	1991	3.596	22.931
Vikna	2 x 500	1993	2.985	13.034
TOTAL	3,855 kW		10.859	64.245

The wind turbines are installed as single units, except for two units at the test site Frøya and five turbines installed in a wind power plant (2.2 MW) at Vikna, northwest of Trondheim. All turbines are connected to the grid system, except for the oldest one at Frøya, which, during experimental periods, makes up part of an autonomous wind-diesel prototype project. Ten of the wind turbines are owned by power companies. These have been installed with the help of a 50% investment subsidy from the wind energy demonstration program. The two others are privately financed and owned.

The wind power plant at Vikna (2.2 MW) yielded during 1997 an energy output of about 6.6 GWh, corresponding to 1,255 kWh / m^2 rotor area. This output was attained at an average wind speed of 7.4 m / s, a capacity factor of 0.34, and an average technical availability at the wind power plant of 91.4%. On an average the wind turbines showed a capacity factor of 0.32, and an average technical availability of about 90%.

No special incidents or particular problems concerning the running of the wind turbines have been reported during 1997.

18.2.2 Installed Conventional Capacity

About half the energy consumption in Norway and nearly all the electricity production is met by hydro-power. An installed capacity of about 27,735 MW hydro-power provides more than 99% of the energy for electricity supply in a normal year. In addition 265 MW thermal power makes a total sum of 28,000 MW installed conventional capacity at the end of 1997. The energy production from wind turbines represents only a minor part of a total electricity consumption of 115.5 TWh in 1997.

18.3 MANUFACTURING INDUSTRY

18.3.1 Status

At present, there are no Norwegian manufacturers of wind turbines. The reason is that the domestic market for wind turbines seems to be too small. Generally, there is a need for cost reductions or some subsidies in the wind energy sector if any essential expansion of the wind turbine market is to be achieved.

Only a few industrial companies are deeply involved in R&D activities on wind energy, with the exception of the industrial involvement regarding the Norwegian wind-diesel prototype system (one company).

Industrial products for the wind energy sector are delivery of polyester resins for turbine blades (one company) and cast iron components for wind turbines (mainly one company).

18.3.2 Technical Developments

The second generation wind-diesel project on the island Frøya (west of Trondheim) is approaching its completion by early 1998. The main objectives of the project have been to operate the system against an isolated group of consumers for an accumulated period of one year in order to gain operating experience with an autonomous wind-diesel power supply system and to carry out long term performance testing.

At the end of 1997, it was about two years since the 55-kW prototype system was put into operation. Although the system has accumulated fewer operating hours than initially planned, a lot of experience was gained and the lessons learned will prove very important for future work in this field. The main conclusions from the project, in terms of system performance results and operating experiences, are summarized below.

The system performance is documented, based on a comprehensive data acquisition from more than eight months of continuous operation. The system operation is verified and compared against initial design objectives such as system control performance, power quality and overall performance in terms of fuel consumption, number of diesel starts etc. The system has during operation, delivered a reliable electricity supply with excellent voltage quality. The fuel savings under normal operation have slightly exceeded expectations most probably due to a positive correlation between wind speeds and consumer load.

Different operating problems have, however, significantly limited the system availability during the project period. The main conclusions regarding system operation and maintenance, can be summarized as follows.

Autonomous wind-diesel systems will typically be used in remote areas (often islands), which are normally exposed to rough climatic conditions. The project has shown that special attention is needed for certain components exposed to wear and that a good supply of spare parts is essential in order to ensure high availability of the system. A reliable wind-diesel system should therefore have more than one diesel generator set available.

The complexity of a wind-diesel system also emphasizes the need for a good control and protection system that can aid operators in finding faults.

The present aim, after completion of the system operation within this project, is to document the overall results and experiences in a final report which is due early 1998.

After completion of this project, the wind-diesel system on Frøya will be used for various research and demonstration purposes. For the industrial partner, ABB Kraft A/S, the system represents the basis for further development of a fully commercial product. Further work will focus on introduction of the wind-diesel technology in the domestic marked, with a view to having one or more installations operating within 1-2 years.

18.4 ECONOMICS

18.4.1 Electricity Prices

The Norwegian spot market prices of electricity at the main grid level for the years 1996-1997 are shown in Figure 18.1. These prices may represent typical buy-back prices for wind generated electricity delivered into the grid transmission system. In addition to these prices there are the grid transmission and distribution costs for low voltage electricity, taxes and levies.

The prices charged to various customer categories are determined by tariff systems, which are made up of a mixture of variable and fixed charges. This gives an average price of electricity of about NOK 0.55/kWh delivered to households in 1997. The industrial electricity prices may vary considerably, but are somewhat lower than for households.

18.4.2 Invested Capital

The total invested capital in the Norwegian wind turbine systems may be estimated at about NOK 42 million (USD 6 millions). About one half of this amount has been given as government grants to the wind turbine owners.

The value of the total wind-generated electricity so far (64.3 GWh) may be estimated at about NOK 13 million. An average generating cost in the hydro-power system of NOK 0.20/kWh has been used as a reference for this estimate.

18.4.3 Project Costs

Based on estimates from recently projected wind power plants along the Norwegian west coast, it may be concluded that the production cost of

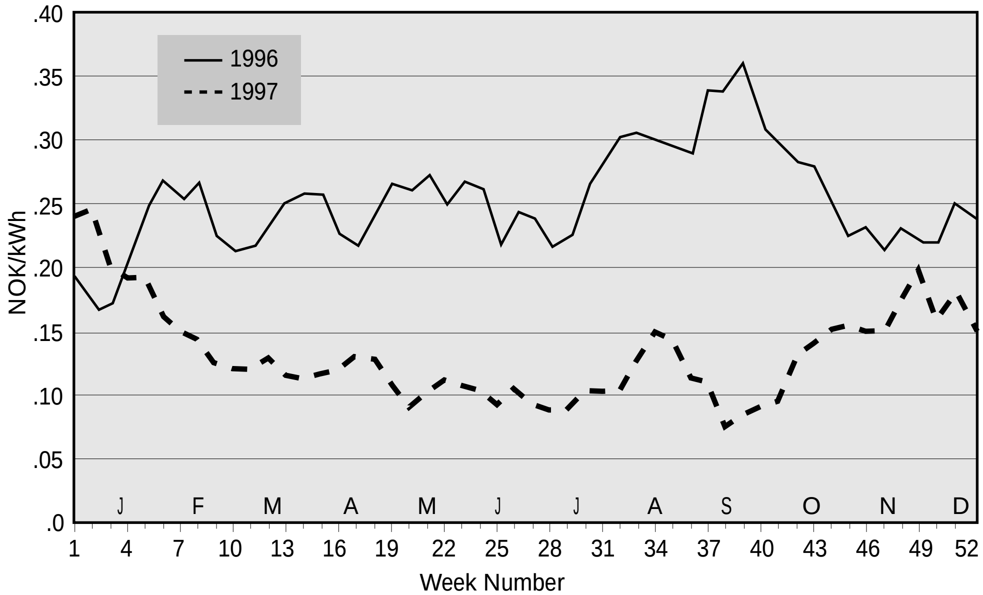


Figure 18.1 The spot market price of electricity at the main grid level in Norway during the years 1996–1997.

electricity from such plants at good sites may be in the range of NOK 0.25-0.30 / kWh, depending on local conditions. It is then assumed that the plant is equipped with commercial wind turbines and financed without state subsidies. This implies that the cost of wind power ought to be reduced about NOK 0.05-0.10 / kWh if a good business economy is to be attained. Accordingly, activities concerning planning and building of wind power plants are expected to remain at a relatively low rate until it becomes more profitable to develop such units.

18.5 MARKET DEVELOPMENT

18.5.1 Market Stimulation Instruments

A growing demand for electricity in the Norwegian market and expectations of some increase of power prices in the coming years have given rise to activities in the planning of wind power installations in 1997. Expectations of state subsidies may also have caused actors in the power market to wish to be prepared if wind power should become profitable in the near future.

Owing to the fact that there are some government grants under consideration, NVE has drawn up the following lines for planned supportive actions in 1998.

Financial support to carry out feasibility studies of wind power projects greater than 500 kW, possible grants corresponding to about 50% of the actual costs, within limits of NOK 150,000 per project;

Financial support in order to introduce cost-effective wind power installations, possible grants within limits of NOK 1,600 / kW installed capacity, corresponding to about 20% of an expected development cost of NOK 8000 / kW installed capacity.

Activities in the planning of wind power installations in 1997 have led to applications for licenses to install three new wind power plants with a total capacity of about 7 MW.

18.5.2 Impact of Wind Turbines on the Environment

The environmental influences of wind power installations will be appraised during the license procedure, along with assessment of the project economy and the disposal of the intended areas.

It may be difficult to indicate savings in environmental benefits with the use of wind energy in a hydro-power dominated energy market. Nevertheless, fuel oil is also used for heating purposes in Norway. If the energy outputs from wind turbines in 1997 were used to substitute for fuel oil for room heating it would be estimated to represent savings of approximately 1,100 TOE (0.105 kg fuel oil / kWh utilized, energy efficiency 0.80).

18.6 GOVERNMENT-SPONSORED R, D&D PROGRAMS

18.6.1 Funding Levels

A combined R&D program on efficient energy technologies and new and renewable sources of energy has been managed by the Research Council of Norway (NFR) since 1994. The program includes subjects such as wind, bio, solar and wave energy. It is divided into two main areas:

Product development, and
Research as a basis for industrial undertakings.

The program mainly focuses on product development for the market. It is the trade and manufacturing industries that are responsible for submitting applications for government grants from the program and implementing approved projects. The quality of the projects and the possibility for sustainable business opportunities determine the priority among the different energy sectors.

The budget for government support of the program in 1997 was NOK 22 million (about USD 3 million). In general, up to 50% of the development costs can be covered by the program, except for basic research activities, which may be covered up to 100%.

Only a minor part of the R&D budget, about NOK 0.5 million (USD 0.07 million) has been assigned for wind energy activities in 1997.

18.6.2 Demonstration and Market Introduction

The Norwegian Water Resources and Energy Administration (NVE) is responsible for running a market introduction program on efficient energy technologies, which also includes technologies for new and renewable sources of energy. Government grants of up to 50% of the total cost are available from NVE for some of these activities. About NOK 68,000 (about USD 9,500) was used under this program in 1997 for running a wind-diesel demonstration project. The introduction activities may, however, be increased in the future with a view to accelerating the processes for making use of wind energy.

18.6.3 Priorities

The R&D priorities in 1997 have been:

A project studying the industrial production of wind turbine blades with a view to producing a prototype blade for testing (one company);
A project concerning numerical analyses of wind turbine blades (a course of academic studies).

The priorities concerning introduction of wind turbines have been:

Preliminary studies of some wind power projects (several actors);
Preparatory work concerning the financing of a demonstration project with a 1.5 MW turbine unit (one power company);
Preparatory work concerning the financing of a planned 3.75 MW wind power

plant in the south of Norway (one power company).

18.6.4 International Collaboration

Participation in international collaboration concerning wind energy has been restricted to activities which are rooted in national activities where the benefit from such participation is obvious, e.g., the participation in IEA R&D Wind and some EU projects.

ABB Kraft A / S participates in the JOULE III project “Power control for wind turbines in weak grids.” Some of the experiences from the work with the second generation wind-diesel system at Frøya may be exploited in this project.

The Norwegian University of Science and Technology, Trondheim, has participated in the JOULE project “Database on wind characteristics.”

CHAPTER 19

19.1 GOVERNMENT PROGRAMS

19.1.1 Aim and Objectives

Spain is a country with excellent wind resources and with a well-developed technology in the wind energy field. This technology has come from the very active participation of Spanish industry in the research and development programs during the past years. At the present time, wind energy has a very promising future in Spain. The estimate for the next year is that over 700 MW will be installed in 47 new wind farms that will allow reaching the milestone of 1,000 MW of wind power in operation in the country during the year.

The main participants in the structure of the Spanish electric supply system are coal-thermo plants (47 %,) hydroelectric plants (36 %) and nuclear plants (16%).

The targets relating to the use of renewable energy sources are described in the Energy Saving and Efficiency Plan (P.A.E.E.) contained in the Spanish National Energy Plan. This Plan foresees an increase of 25% in the use of renewable energy for the year 2000 compared to 1990.

The Spanish Government is supporting the use of renewable energies and their policy is in agreement with the general objectives defined in the European Union: economic growth, creation of employment, maximum self-sufficiency, and raising of the quality of life of inhabitants through improved environmental conditions.

The wind goal of 168 MW by the year 2000 foreseen in the P.A.E.E. has been widely surpassed reaching and exceeding such amount in the year 1996.

Figure 19.1 Distribution of installed capacity at the end of 1997 shows the existing wind installations distributed by regions at December 31st 1997.

19.1.2 Strategy

The strategy followed for the development of wind energy in Spain has been implemented in several steps. At the beginning and during the period 1980 to 1985, the program focused on assessing national resources and also developing the national technology. As a result of the programs (national, and utilities program), two of the present leaders of the Spanish industry, Made and Ecotécnia emerged with wind turbines developed in the range of the 20-30 kW. During the period 1985-90, the continuation of the resource assessment at the regional level and the demonstration program launched by the public organization IDAE (Institute for Diversification and Saving of Energy) for installation of several small wind farms allowed the consolidation of the newly created industry. At that time, CIEMAT, the main public research center in the field of energy research in Spain, started activities in wind energy through the development of the AWEC-60 project (a 60 m diameter, 1,200-kW wind turbine) inside the R&D program of the DG XII of the European Union.

Finally, in the period 1990-95, the definitive impulse (once the Spanish industry was ready to fulfill the requirements of the future market) was the publication of Royal Law of 2366/1994. This law guarantees the electricity price to be paid by the utilities to the wind power plants. This was the beginning of a new era of wind energy in the country.

19.1.3 Targets

The majority of the autonomies have regional wind energy programs that add to a total target of more than 8,000 MW to

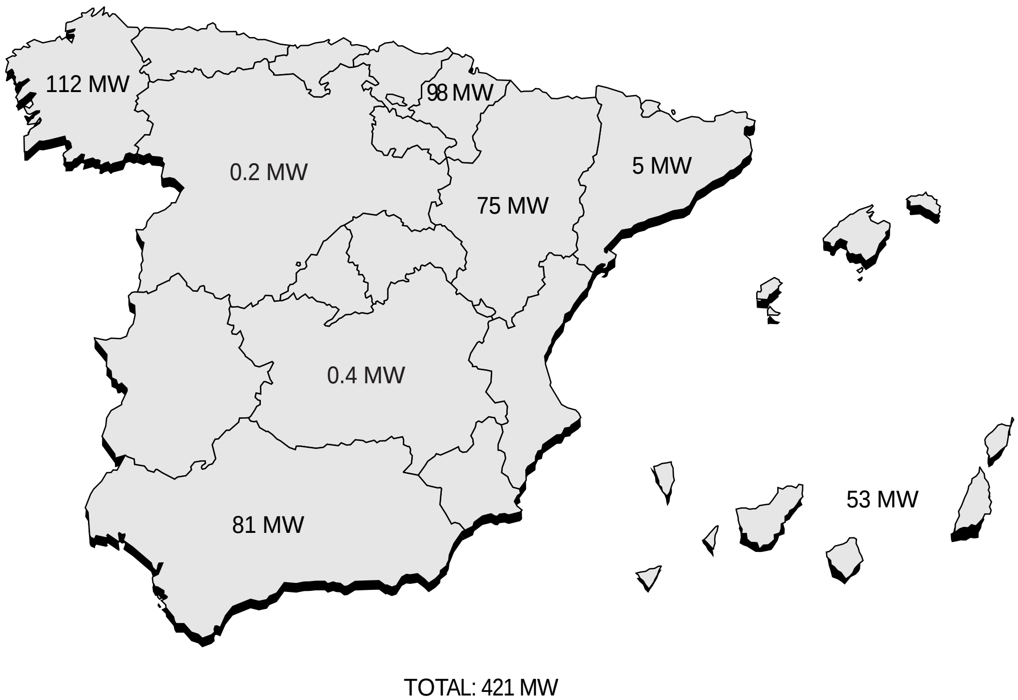


Figure 19.1 Distribution of installed wind energy capacity at the end of 1997.

be installed in the next decade. Table 19.1 Estimated Power by Region shows these estimates.

19.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

19.2.1 Installed Capacity

During 1997, a significant advances were made in wind energy in Spain. A total of 477 new wind turbines were installed in 14 wind farms, with a total output capacity of 205 MW. The total power installed at the end of 1997 was 421 MW. The power installed has been doubled in one year (216 MW at December 1996). (See Figure 19.2)

The wind turbines installed are between 300 to 600 kW of rated power. The majority of the installed capacity in 1997 was using wind turbines manufactured in Spain (Gamesa Eólica, Made, Ecotécnia, and Bazan-Bonus). Table 19.2 lists the new wind farms installed in 1997.

The predictions for the year 1998 (based on ongoing projects) foresee the installation of another 760 MW from more than 1500 wind turbines in 46 new wind farms. That supposes an increase for 1998 of 178% in power. At the end of 1998 the total power installed will surpass 1000 MW.

The new wind farms will be large- and medium-sized, the biggest being a 50-MW wind farm (84 units of 600 kW).

The wind farms to be installed in Spain are mainly owned by consortiums formed by utilities, regional institutions involved in local development, private investors, and, in some cases, the manufacturers. Private individuals are not taking an important role in the development of wind energy in Spain.

Table 19.1 Estimated Power by Region.

REGION	ESTIMATED POWER (MW)	YEAR
Galicia	2800	2007
Aragon	1000 2500	2007 2012
Navarra	220 650	2000 2010
Andalucia	500	2000
Islas Canarias	150 300	1998 2002
Cataluña	300 1000	2005 2010
Castilla-Leon	250 1000	2000 2005
Murcia	50	2000
Pais Vasco	500	2005

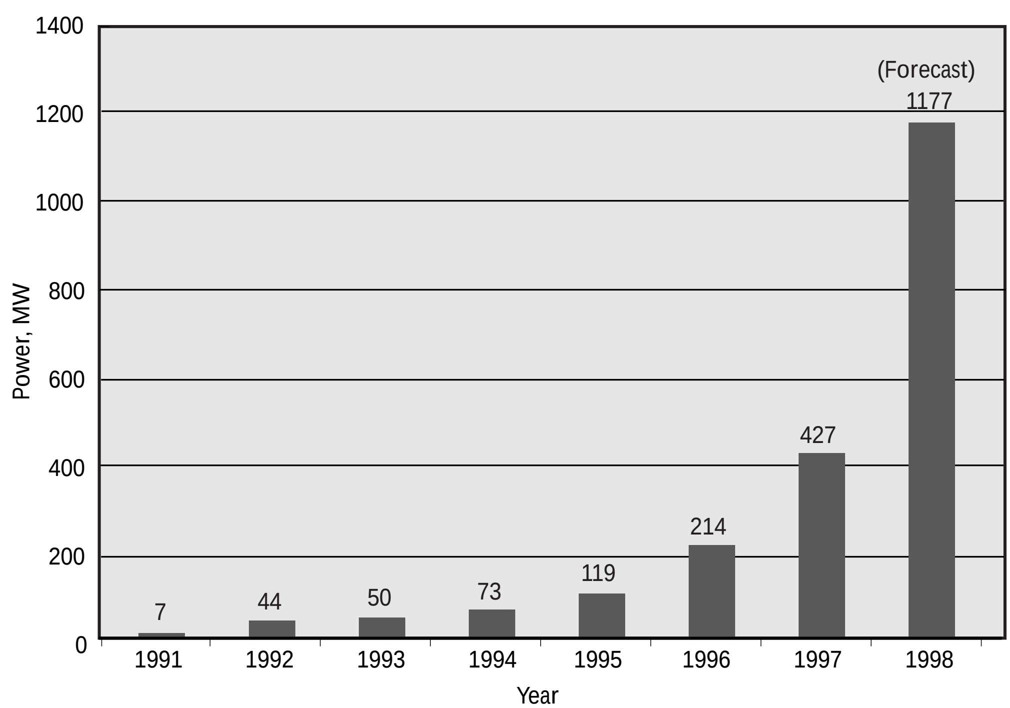


Figure 19.2 Wind installations in Spain.

Table 19.2 Wind Farms Installed in 1997.

WIND FARM			WIND TURBINE			
NAME	LOCATION	POWER (MW)	MANUFACTURER	MODEL	RATED POWER (kW)	NO. TURBINES
SAN MARTÍN DE UNX II	SAN MARTÍN DE UNX (NAVARRA)	11.4	GAMESA EÓLICA	G-42	600	19
LERGA	LERGA (NAVARRA)	19.8	GAMESA EÓLICA	G-42	600	33
LEOZ	LEOZ (NAVARRA)	24.6	GAMESA EÓLICA	G-42	600	41
AGAETE	AGAETE (GRAN CANARIA)	1.32	MADE	AE-30	330	4
SANTA LUCIA	SANTA LUCIA (GRAN CANARIA)	5.3	MADE	AE-30	330	16
MALPICA	BERGANTIÑOS (LA CORUÑA)	15.07	ECOTECNIA	28/225	225	67
LA CAPELADA	CEDEIRA Y CARIÑO (LA CORUÑA)	16.5	MADE	AE-30	330	50
PASAREIRAS I	MUROS Y CARNOTA (LA CORUÑA)	20.4	BAZAN-BONUS	Mk IV	600	34
PASAREIRAS II	MUROS Y CARNOTA (LA CORUÑA)	18.3	BAZAN-BONUS	Mk IV	600	32
BARBANZA	BOIRO (LA CORUÑA)	19.8	MADE	AE-30	330	60
PUNTAZA DE REMOLINOS	REMOLINOS (ZARAGOZA)	9	GAMESA EÓLICA	G-42	600	15
LA MUELA II	LA MUELA (ZARAGOZA)	13.2	MADE	AE-30	330	40
PARQUE DEL PILAR	LA MUELA (ZARAGOZA)	15	GAMESA EÓLICA	G-42	600	25
ENIX	ENIX (ALMERIA)	13.2	MADE	AE-30	330	40

Figure 19.3 Leoz Wind Farm (Navarra).

19.2.2 Operational Experience

The production data of wind power plants for 1996 is summarized as follows:

Power Installed 12/31/96	216 MW
Energy Produced	370 GWh
Average Capacity Factor	0.29
Specific Annual Energy	1074 kWh/m^2
Equivalent Full Load Hours	2584

From the analysis of the production dat of the wind turbines operating in Spain in 1996, the average capacity factor is 0.29, equivalent to 2584 hours per year at full load. The following shows the result of the analysis:

Capacity Factor, %	% of the Wind Turbines
<20	5.8
20–30	50.0
30–40	39.0
>40	7.2

About the specific energy production (ratio between annual energy and rotor area of the wind turbine), the average value for 1996 was 1074 kWh/m^2, and the following distribution:

Specific Energy (kWh/m^2)	% of the Wind Turbines
<500	2
500–1000	35
1000–1500	52
>1500	10

Table 19.3 shows the comparison with the previous years.

There is an increase in the average capacity factor and in the specific energy for the year 1996 over the years 1994 and 1995.

19.3 ECONOMICS

19.3.1 Electricity Prices

In December 1994, the Spanish government introduced Royal Law 2366, which regulates the price to be paid to self-generators. This covers cogeneration, minihydro, photovoltaic, and wind power plants.

Table 19.3 Wind Turbine Production Data.

	1994	1995	1996
Power Installed at December 31	70 MW	125 MW	221 MW
Average Capacity Factor	0.26	0.28	0.29
Specific Annual Energy	981 kWh/m^2	1040 kWh/m^2	1074 kWh/m^2
Equivalent Hours at Full Load	2277	2453	2584

The aim of the regulation is to increase energy production from non-conventional power generation plants from 4.5% in 1990 to the target of 10% in the year 2000. This regulation brings the existing regulations together in a single text and develops the basic criteria for technical and economic relations between owners and utilities. The regulation applies to wind power plants up to 100 MW. The newer law of November 27, 1997 (D. 54/1997) updates the prices for the next years.

The average value paid for the electricity generated for the wind power plants during 1997 was 12 Pts/kWh, with small variations depending on some specific conditions. The average sale price of the electricity to the consumers for the year 1996 was 14.54 Pts/kWh, going from average prices for the industrial sector between 9-11 Pts/kWh to the 16.3 Pts/kWh for domestic users.

19.4 INDUSTRY

All this important activity in the wind energy field has stimulated the development of the Spanish wind industry. This industry includes not only the manufacture of complete wind turbines, but also the manufacture of components for the wind industry: blades, generators, gear boxes, towers, wind sensors, etc. Also the service sector (installation, maintenance, engineering) has grown in the last year.

Five companies are leading the national Spanish industry: Ecotecnia, Made, Bazan-Bonus, Gamesa Eólica and Desa.

Ecotecnia started activities in wind technology development in 1981, meaning it now has more than seventeen years of experience in that field. During 1997 Ecotecnia installed 67 windturbines of the model 28/225 of 225 kWt. The two prototypes ECO/41 and ECO/44 of 500 kW and 600 kW that were tested during 1997. Both designs are three-bladed, stall-controlled wind turbines, incorporating a very advanced design in the drive train. The ECO/44 is now in the market for commercialization and the first wind farm using this technology will be connected to the grid in March of 1998. Also the Cabanillas windfarm in Navarra, consisting of 50 ECO/44 wind turbines (30 MW), is scheduled to start operation in June 1998. For 1998 Ecotecnia plans to install 100 MW in eight wind farms

Made is another of the pioneer companies in Spain that has developed ten different models of wind turbines since 1982. They have progressed from the first design, a 24-kW turbine, to the last AE-45, 600 kW. At the present time, Made is concentrating their commercial effort on the model MADE AE-30 (330 kW). During 1997 Made installed 210 Made AE/30 wind turbines making a total of 70 MW. Two prototypes (one using aerodynamic stall control and the other pitch control) of 500 kW, the AE-41, are also in the testing

Table 19.4 European Wind Projects with Spanish Participation.

PROGRAM	COORDINATOR	SPANISH PARTICIPANTS	PROJECT TITLE
JOULE	CRES (GR)	CIEMAT ECOTECNIA	Investigation of design aspects and design options for wind turbines operating in complex terrain environments (COMTER.ID)
JOULE	City University (UK)	ECOTECNIA	Wind turbine blades equipped with air-jet vortex generators
JOULE	EUREC AGENCY	CIEMAT	European Wind Turbine Standards II (EWTS-II)
JOULE	Univ. of Madrid (SP)	Univ. of Madrid CIEMAT	Smart Technologies Applied to Wind Turbine Blades (SMART-BLADES)
JOULE	ITC-CIEA (SP)	ITC-CIEA CIEMAT Univ. Las Palmas	Seawater Desalination Plants Connected to an Autonomous Wind Energy System (SDAWES)
APAS	LAMDA (GR)	CIEMAT	Utilization of wind, solar and biomass resources in Mediterranean rural regions
APAS	ITER (SP)	ITER CIEMAT Univ. Las Palmas	Towards the large scale Development of Decentralized Water Desalination (Prodesal - Pro Desalination)

phase at the Monte Ahumada Wind Farm, in the Tarifa area. Made started the production of the AE-41 during 1997. Also two prototypes of 600 kW and 660 kW, (MADE AE-45, specially designed for low wind conditions, and MADE AE-46) will start operation in early 1998. For 1998 Made plans to install 150 MW in 10 wind farms. MADE has signed a contract to install a 13.6 MW wind farm in China.

Gamesa Eólica is manufacturing wind turbines of 600 kW, the G-42 using Vestas Technology. The majority of the components are already manufactured in Spain (including blades). During 1997, Gamesa installed 133 units of the G-42 with a total of 80 MW. For next year Gamesa Eólica plans to install 250 MW in 10 wind farms and to start commercialization of the G-47, a 660-kW wind turbine designed for low wind speed conditions. They also plan to install a wind turbine of 1650 kW, the prototype G-66.

Desa manufactures wind turbines of 300 kW and is developing a new wind turbine in the range of 600-700 kW. The Zas wind farm (61 units of the model DESA-300 of 300 kW) will start operation in early 1998. For 1998 Desa foresees the installation of 80 MW in four wind farms.

Also there are other Spanish manufacturers active in the wind energy industry using foreign technology (Taim-Nordtank, Acsa-Vestas, Bazan-Bonus...) that will increase the capacity of the Spanish industry to fulfil the domestic and international market. In particular Spanish manufacturers are participating in the planning of projects in North Africa (Tunisia, Morocco, Egypt, ...). They are also increasing their marketing activities in other countries (India, China, South American countries, ...)

19.5 RESEARCH, DEVELOPMENT AND DEMONSTRATION PROGRAM

19.5.1 R&D Program

The main R&D organization in the field of wind energy in Spain is CIEMAT, a public center for research in the technological and environmental aspects of the energy production. Inside CIEMAT, the Department of Renewable Energies (DER) is active in several projects including resource evaluation, blade development and testing, wind turbine testing, design and modeling of components, and stand-alone applications with emphasis on water desalination. Other research centers are also very active, as for example ITER and ITCAN in the Canary Islands, etc.

In the last years, the R&D is expanding from pure R&D centers into industry. For example, several of the Spanish wind manufacturers have their own testing facilities (for instance MADE and

Figure 19.4 Baix Ebre Wind Farm (Mount Buinaca in Tortosa).

ECOTECINIA in the Tarifa area) where they perform research activities in specific fields. They mainly work to develop advanced technological options, such as variable speed systems, power control strategies, etc.

As a consequence of increasing activity, the number of University Departments working on projects is rapidly increasing. In particular the Politechnical University of Madrid continues studying wakes in wind turbines, electrical systems, and blade technology. The University of Navarra is actively working on lightning in wind farms. The Vigo University is developing a simplified methodology for flicker analysis and voltage and frequency variations in wind farms. The University of Las Palmas (Canary Islands) works on the impact of wind farms on grid stability. They are also looking at desalination plants powered by wind energy systems.

The funds for R&D in wind energy come from the budget of the wind energy department of CIEMAT. For 1996 this budget was around 300 Mpts. For demonstration projects in 1996 the public funding was 3,000 Mpts (20 MECUs).

The majority of the R&D activities in wind energy in Spain are developed under the umbrella of the European R&D programs. A list of the main European projects with Spanish participation are listed in Table 19.4.

The first megawatt wind turbine installed in Spain is the AWEC-60 project developed inside the WEGA I program of the DG XII in 1989. The Wind Turbine was retrofitted with a new set of blades and restarted operation after summer 1997.

At the present time, the Spanish manufacturers are planning to start new developments in large wind turbines, as soon as their present developments in the range of the 500-700 kW are commercial. However, the general position about large wind turbines is not so enthusiastic as in other European countries, mainly due to the particular Spanish topography. In Spain the windy areas are located mainly in mountainous regions, with difficult access that makes the transport and erection of large machinery expensive. There are no clear advantages that large towers have in offshore or plain terrain installations.

19.5.2 Demonstration Program

The National Energy Plan (PEN-91) includes the 1991-2000 Energy Saving and Efficiency Plan (PAEE), which describes the subsidies for renewable energies. These subsidies vary according to specific circumstances. For the wind sector in 1997 the subsidies included two options:

1. Wind farms with exceptional conditions: access complicated, high cost in the power line or areas with low winds. It was possible to get a subsidy up to 30% of eligible cost for up to a maximum of 20 MW of power installed, in one or several wind farms, with commercial wind turbines of the same technology.
2. Single wind turbines for particular applications: isolated systems (including non-grid connected application) and applications accessing high or very low winds. The maximum subsidy was up to 30% of eligible cost.

The new electric law has been effect since November 27, 1997, and represents a liberalization of the electrical power market, opening the market to private enterprise. The liberalization policy is conceived to be compatible with the pursuit of target objectives such as, for example, energy efficiency, consumption reduction, and environmental protection. Measures to encourage the exploitation of renewable energy sources are incorporated in the new law. The present conditions to be applied for the wind generation plants are going to be maintained for the next years.

CHAPTER 20

20.1 GOVERNMENT PROGRAMS

20.1.1 Aims and Objectives

As set out in 1991, the objective of Sweden's energy policy is to secure the long-term and short-term supply of energy on internationally competitive terms and to promote economic and social development based on environmental sustainability. The policy specifies that the national energy supply is to be secured by an energy system based, as far as possible, on sustainable, preferably indigenous and renewable resources and on energy efficiency. Sweden's energy policy approach places considerable emphasis on economic and environmental objectives.

Based on these principles, an Energy Commission (published December 1995) made up of Parliamentary representatives was established in 1994 to review the basics of Sweden's energy policy. The Commission's work was meant to clarify, among other things, whether current energy policy programs are sufficient to meet the combined targets and aims of energy, economic, and environmental policies.

The findings of the Commission reaffirm the policy objectives set out in the 1991 Energy Bill, as stated above. Results of energy efficiency improvements, supply of renewable energy, and the options for maintaining internationally competitive prices are to determine the speed at which nuclear power is phased out. Further, the Commission finds that an exact time limit setting out the year in which the last reactor is to be taken out of service should not be specified. On the other hand, it finds that the phase-out should be commenced at an early stage to ease the adjustment process and that it is possible to close one nuclear reactor by 1998 without adverse affects on the power balance.

On February 4, 1997, an inter-party Energy Policy Agreement between the Social Democrats, the Centre Party and the Left Party was reached. One reactor shall be closed down before July 1, 1998 (Barsebäck I), and the second reactor (Barsebäck II) before July 1, 2001. A new, long-term transformation program to develop an ecologically sustainable energy supply system has been decided

20.1.2 Government R,D&D

Sweden has a good wind energy resource and was one of the first countries to embark on a wind energy program in 1975. The government is supporting the development and installation of wind turbines in two programs managed by the Swedish National Board for Industrial and Technical Development (NUTEK):

A fully financed research program with a three year budget of SEK 21 millions for 1994-1997.

A development and demonstration program for wind systems, with a maximum of 50% support.

For 1998 the wind energy program has been increased compared to previous years. The budget for late 1998 to year 2001 is still not set, however.

The utilities are engaged in studies, demonstration, and evaluation projects. Since 1994, the research and development activities of these utilities have been coordinated in a jointly owned company, Elforsk AB, which initiates and finds sponsors for projects in the field of power generation. In addition to the activities of Elforsk AB, the largest utility, Vattenfall AB, has a substantial wind energy development program of its own.

20.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

20.2.1 The Electricity Market

The Electricity Act which provided the framework for the Swedish electricity market for several decades originates from 1902. On January 1, 1996, a new Electricity Act came into force. The aim of the new act is to introduce competition in the electricity market, thus creating the conditions for efficient pricing and a more open trade in electricity. Competition in trade in electricity makes it possible for buyers to choose freely between different vendors on the market.

As a consequence, the Swedish State Railways (SJ), McDonald´s at Rissne outside Stockholm and other companies have decided to buy electricity produced by wind power through their suppliers.

The new electricity market incorporates regulations for small-scale production. Before the reform, the holder of a regional power concession was responsible for purchasing electricity from all small power generation plants up to 1,500 kW located within the distributor's region. The price was set as "avoided cost." With the aim of protecting the small power producers during the transition to the new competitive electricity market, a delivery concession has been introduced in the Act for a limited period of time (year 1998-2001). The holder of a delivery concession is responsible for purchasing electricity from each power generation plant (<1,500 kW) located within his region.

The price is decided to be equal to the household tariff minus reasonable costs for administration and profit. The wind turbine owner also gets an income from the net owner related to the value of the decreased net losses. The deregulated market also gives the possibility to the turbine owner to sell his electricity to any customer. This gives opportunity for a "wind electricity market."

20.2.2 Installed Wind Energy Capacity

In the early 1980s, two Swedish MW-sized prototypes and a few 50-kW units were erected in Sweden. From 1988 onwards, commercially available wind turbines were introduced at a notable rate, amounting to a total of 5 MW when the investment subsidy was introduced in July 1991. Since then the amount has increased to a total of 122 MW (December 31, 1997) and an annual electricity production of about 205 Gwh. The total installed capacity in Sweden is shown in Table 20.1.

Table 20.1 Total Installed Electricity Capacity in Sweden in 1997.

GENERATOR TYPE	1997 MW	1997 TWh
HYDRO POWER	16,150	68.3
NUCLEAR POWER	10,050	66.9
THERMAL POWER PRODUCTION (CHP, cold condensing)	7,400	9.5
WIND POWER	122	0.205
NET IMPORT		5.1
TOTAL	33,722	150.0

Historically, wind power plants have been owned by private companies, either directly by individuals and private companies (mainly active in other areas than energy production) or owned as shares in companies and partnerships. Over recent years, this dominance has increased. During 1996, however, the utilities have increased their market share compared to 1995 (Figure 20.1).

20.3 MANUFACTURING INDUSTRY

20.3.1 Status / Numbers / Sales of Manufacturers

Three manufacturers develop medium and large wind turbines in Sweden: Kvaerner Turbin AB, Nordic Windpower AB, and Zephyr Energy AB.

Kvaerner Turbin AB has developed and sold Näsudden I (2000 kW) and

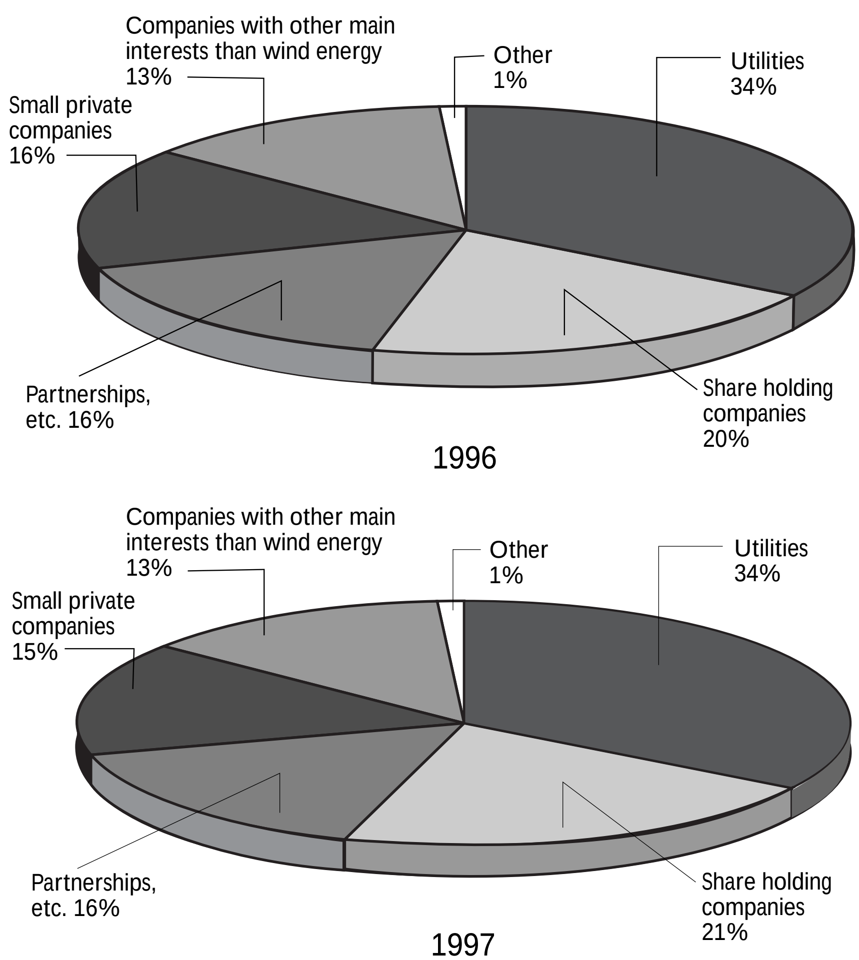


Figure 20.1 Owners of wind turbines in Sweden (December 31, 1997).

Näsudden II (3000 kW). Vattenfall AB is the purchaser of both turbines.

Nordic Windpower AB has developed and sold Nordic 400 (400 kW at Lyse Wind Power Station) and Nordic 1000 (1000 kW at Näsudden, Gotland). Vattenfall AB is the purchaser of both turbines.

Zephyr Energy AB has developed and sold seven 250-kW turbines. The local distribution company Falkenberg Energy and Vattenfall AB are the purchasers of six of the turbines.

20.4 ECONOMICS

Electricity trade is pursued in different markets, which also involves a range of electricity prices. Bulk power price is the price of electricity at the main grid level and serves as a basis for the prices paid by end customers and distributors. The difference consists principally of the costs of administration and transmission.

The prices in the market for high-voltage electricity paid by certain customers, industrial plants and distributors may be close to the bulk power price. In the market for low-voltage electricity, the distribution costs are considerably higher, and the price of bulk power as a proportion of the price paid by the end customer is consequently relatively low at just under one-third of the price, excluding taxes, payable by a household without electric heating (Table 20.2). The prices charged to various customer categories are determined by tariff systems which are made up of a mixture of variable and fixed charges.

20.4.2 Turbine / Project / Generation Costs

At good sites, today's commercial wind power plants of up to 600 kW can produce electricity at a cost of SEK 0.26 - 0.32 / kWh (without state subsidy) depending on the site. In Sweden, support is generally required for wind power to be viable.

Table 20.2 Total Price of Network Service and Electricity on July 1, 1997, in Sales of Electricity under the Terms of a Delivery Concession to Various Typical Customers, 0.01 SEK / kWh.

CUSTOMER TYPE	TOTAL PRICES WITH TAXES	PRICES OF NETWORK SERVICES AND ELECTRICAL ENERGY WITHOUT TAXES	
	MEAN VALUE	NETWORK	ELECTRICAL ENERGY
Apartment	99.9	41.1	29.2
Single-family house without electric heating	92.4	36.2	27.6
Single-family house with electric heating	72.2	21.6	25.9
Agriculture or forestry	71.8	22.5	24.9
Small industrial plant	40.9	16.5	25.6
Medium-sized industrial plant	33.2	9.3	24.4
Electric-intensive industrial plant		5.7	23.7

Source: "Prices of electrical energy and network service in 1997," E11 SM 9602, Statistics Sweden

Table 20.3 Estimated Total Average Investment Costs and Annual Production from Wind Turbines in Sweden.

TURBINE SIZE	SEK/kW	MWh
1500 kW	10,870	3,870
600 kW	8,000	1,260
400-500 kW	9,800	1,180
200-250 kW	10,500	560

The wind power plants that are erected today have a capacity between 150 and 600 kW with a majority being the larger wind energy conversion systems. The total investment (average) costs for different Swedish wind turbine projects are shown in Table 20.3. As an average, the costs for the wind turbine is about 80 % of the total investment cost.

20.4.3 Invested Capital and Value of Generated Power

The total invested capital from installation of commercial wind turbines in Sweden so far is approximately 1,050 MSEK (calculated from the year 1991). The price paid for wind turbine produced electricity during 1996 was around 0.26 SEK / kWh (including net value payment). The value is increased by an "environmental bonus," at SEK 0.138 per kWh. The "environmental bonus" is a subsidy from the government and corresponds to the electricity tax for households. For 1998 the Parliament has decided an increase to 0.152 SEK / kWh.

20.5 MARKET DEVELOPMENT

20.5.1 Market Stimulation Instruments

A second market stimulation program (15% investment subsidy) started July 1, 1997. This and the environmental bonus for wind turbines with a capacity less than 1,500 kW are the subsidies that exist today.

In 1995 NUTEK initiated a technology procurement process in order to further reduce the cost for electricity produced by wind turbines. The key purpose was to minimize the technical and economic risks for the buyer by clarifying important technical and economic requirements, and to make sure that predicted performance actually will be delivered. The predicted performance of the first erected wind turbine is under evaluation.

20.5.2 Constraints

20.5.2.1 Environmental Impact

Public attitude toward wind power, especially its impact on the landscape, is a most important factor that influences practically every wind project. Noise emission is also important, but may be seen rather as a "technical" problem. So far the impact on bird life has been minimal.

Objections from the military due to the impact on the landscape have also stopped many wind projects. The military want to avoid disturbances of military micro-wave links, radar, intelligence activities, and aircraft at low altitudes.

20.5.2.2 Public Attitudes

An investigation on the public attitudes towards two wind power plants has been carried out by Vattenfall AB at its test station Lyse in the municipality of Lysekil on the West Coast (north of Gothenburg). The investigation has included both inhabitants and summer residents around the plants and some politicians and civil servants from the municipality. A majority of the people interviewed had a positive attitude towards wind power. In the summer resident area there were more doubts about wind power plants.

20.5.2.3 Noise

Noise is a subject frequently discussed in wind turbine projects. The studies on assessment of wind turbine noise have shown that not only the sound level and its temporal pattern, but also several other factors are important to the subjective responses of people. The major interest is presently concentrated on the noise immission, that is, how to measure and assess wind turbine noise at sensitive areas in the vicinity of a turbine or a group of turbines. Work is continuing on how to describe the noise disturbances in physical terms.

20.5.3 Institutional Factors

In the spring 1995, the Swedish Board of Housing, Building and Planning (Boverket) issued *General Guidelines 1995:1; Establishing land-based wind power, advice and information*. It had been drafted jointly with the Environmental Protection Agency and NUTEK. The publication sets out regulations on the establishment of land-based wind power plants, provides advice, and supplies background information on the characteristics of wind power.

Being Sweden's central governmental agency regarding energy, NUTEK also has the responsibility for claiming areas of national interest for energy production. For wind power NUTEK decided in December 1996 on the principles for how to proceed and the actual project started in 1997. Primarily, areas corresponding to an electricity production of 1 TWh will be identified and another 1 TWh will be identified as a reserve. These areas will need to have a minimum energy content of 4000 kWh/m^2 at 100 m height. Areas concerning national parks, nature resorts and animal protection areas will not be included. So far NUTEK's work with areas of national interest for wind power production only include land based plants in the southern parts of Sweden.

20.6 GOVERNMENT-SPONSORED R, D&D PROGRAMS

20.6.1 Research and Development

20.6.1.1 Scope

The overall goal for the Swedish wind energy research program is to develop knowledge within the wind energy area so that it will be possible to manufacture and develop wind turbines and utilize the wind energy efficiently in the Swedish energy system.

20.6.1.2 Financing

Wind energy research and development in Sweden has a budget of 9 MSEK during the fiscal year 1997. The work has mainly been carried out and administrated by a consortium named Vindkraftskonsortiet (VKK). The consortium was formed in 1994 and comprises the following three organizations: The Aeronautical Research Institute of Sweden (FFA, leader of the consortium), Department of Power Electronics at Chalmers University and Department of Meteorology at Uppsala University. More information can be found at the following WWW-page: http://www.ffa.se/windenergy/windenergy.html.

20.6.1.3 Research Topics

The participants in the consortium are responsible for the following research areas *FFA* (aerodynamics, structural mechanics, materials), *Chalmers* (electric machinery and control technology, test station at Hönö) and *Uppsala University* (atmospheric research, wake effects and boundary layer phenomena).

The basic research within these topics is combined into cooperation projects with the goal to develop suitable tools for analysis and design of wind energy conversion systems. These projects will aim at developing methods for lighter and more flexible wind energy conversion systems. Such machines require better understanding and prediction methods for the general behavior and structural response of the wind energy conversion systems.

An area of uncertainty is within the field of aerodynamics. Questions regarding blade behavior at stall and the influence of three dimensional flow have been given extra attention lately. Methods suitable for implementation into structural codes have been developed. These calculation tools have been verified during the evaluation of Nordic 400.

Wind resource assessments in the northern mountainous parts of Sweden as well as offshore have been studied in order to make wind resource knowledge more complete. Special attention has been given to understanding turbulence, shear and wind direction behavior at such sites. Meteorological phenomena in wind farms have also been studied. Results illustrate the importance of considering atmospheric conditions when describing the structure of a wind turbine wake.

The test station at Hönö on the Swedish west coast has been used to test and validate different control system algorithms. It has also been of great value for testing power electronics systems. A direct drive generator system project has been initiated and will be tested at Hönö in order to develop effective systems.

20.6.2 MW-Rated Turbines

Nordic 1000

The 1 MW Nordic 1000 wind turbine (thoroughly described in *IEA Wind Energy Annual Report 1994*) was erected in early April 1995. During 1997 it produced 1736 MWh. The total from start was 3,462 MWh.

Näsudden II

The 3000 kW Näsudden II has until December 31, 1997 produced 19 623 MWh. The gearbox repair was finished in June and the operation restarted on June 30. The production during 1997 was 2102 MWh.

20.6.3 Offshore Siting

Nogersund

Since 1991 there has been a research program concerning the impact on the environment from the 220 kW offshore wind power station at Nogersund. The bird migration lines pass very near the station. Despite this, the impact on birds turned out to be none. The resting birds got used to the station and the migratory birds noticed the station and flew further away from the turbine. Nogersund is the biggest fishing harbor in the south of Sweden. Therefore it was important to examine the impact on fish and fishing. The foundation of the station turned out to be a construction which attracted many fish. Another result was that there were no disturbances from the wind power station concerning radar in fishing boats.

Bockstigen, Valar

Vindkompaniet anticipates building a demonstration plant 4 km offshore of Näsudden on Gotland. The project consists of five plants, each of 500 kW (Table 20.4). The Bockstigen Valar project is sponsored by EU (THERMIE).

Table 20.4 Project Data Bockstigen, Valar 2.5 MW

Capacity	5x500 kW
Calculated average wind, 40 m height	8 m/s
Calculated annual electricity production	8 GWh
Calculated construction cost	32.2 million SEK

The turbines delivered their first electricity to the main grid in March 1998.

20.6.4 International Collaboration

International cooperation has increased significantly during the last few years. Most of the cooperation is carried out in the framework of EU and IEA. Sweden participated in a number of JOULE II and III projects during 1996. The experiences from this type of project are very positive in that they provide opportunities to exchange and develop knowledge in a structured way. The joint financing also supports projects which otherwise not would have been possible. Swedish researchers and companies are therefore looking forward to continuing the work within IEA and the next phase of the JOULE/THERMIE programs.

CHAPTER 21

UNITED KINGDOM

21.1 GOVERNMENT PROGRAMS

21.1.1 Aims and Objectives

Policy. Former government policy has been to stimulate the development of new and renewable energy sources wherever they have prospects of being economically attractive and environmentally acceptable in order to contribute to:

Diverse, secure and sustainable energy supplies;
Reduction in the emission of pollutants;
Encouragement of internationally competitive industries.

The present government proposes a new and strong drive to develop renewable energy sources in line with its manifesto commitment, and believes in increasing the amount of the UK's energy resources that come from renewable energy. A policy review announced by the Minister for Science, Energy and Industry is considering what will be necessary and practicable in order to achieve 10% of the UK's electricity needs from renewables by the year 2010. An announcement is expected during 1998.

21.1.2 Strategy

The government has initiated a market enablement strategy to implement its policy, stimulating the development of sources and industrial and market infrastructure so that new and renewable sources are given the opportunity to compete equitably with other energy technologies in a self sustaining market. For wind energy, the strategy seeks to encourage its uptake by:

Stimulating an initial market via the Non-Fossil Fuel Obligation;
Stimulating the development of the technology as appropriate;
Assessing when the technology will become cost effective;
Quantifying the associated environmental improvements and disbenefits;
Removing inappropriate legislative and administrative barriers;
Ensuring the market is fully informed.

The government also seeks to encourage internationally competitive industries to develop and utilize capabilities for the domestic and export markets.

Market Stimulation - There is a requirement on the electricity supply companies in the UK to provide a proportion of their supply from renewable energy sources; the requirement is set out in the Government's Renewable Energy Obligations. There are separate obligations for England and Wales (the Non-Fossil Fuel Obligation - NFFO), Scotland (the Scottish Renewables Obligation - SRO) and Northern Ireland (the Northern Ireland Non-Fossil Fuel Obligation - NI-NFFO). The additional costs incurred by the companies in buying non-fossil fuel power to meet their obligation are passed on to the consumers.

In November 1997 arrangements were announced for the fifth round of bidding under the Non-

Fossil Fuel Obligation with the expectation that the order would be made in late 1998. A similar announcement of the third Scottish Renewables Order was also made.

Government R, D and D Program - The government (through its Department of Trade and Industry - DTI) supports a program aimed at helping industry to improve its market share both at home and abroad and nearly all expenditure is now on the development, demonstration and monitoring of projects to help reduce the cost of wind energy and improve our competitiveness. Industry is expected to take full responsibility for addressing issues such as public acceptability, electrical integration and environmental impact. An essential adjunct is dissemination of information arising from both directly funded work and from projects in the Renewable Energy Orders.

21.1.3 Targets

As discussed above, during the year a policy review of what would be necessary and practicable in order to achieve 10% of the UK's electricity needs from renewables by the year 2010 was instigated. An announcement is expected during 1998.

21.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

21.2.1 Installed Capacity

A total of 84.5 MW of rated capacity were installed in the UK during the year. This brought the total installed capacity under the Renewable Energy Orders at the end of 1997 to 313 MW (731 turbines). Table 21.1 shows the growth of this capacity with time.

During 1997 the following progress was made in each of the Renewables Orders: *NFFO (England & Wales).* Seven of the projects awarded contracts under NFFO-3 were commissioned with a total rated capacity of 62.4 MW. In February 1997 the fourth and largest renewables Order was laid before Parliament whilst the arrangements for NFFO5 were announced in November 1997.

Northern Ireland NFFO. The sixth and final wind farm of 5 MW rated capacity to be awarded a contract under NI-NFFO-1 was commissioned. The total installed capacity under NI-NFFO1 is now 30 MW.

Scottish Renewable Energy Order (SRO). Two adjoining wind farms, totalling 17 MW, were commissioned under SRO-1 bringing the total installed capacity to 51.8 MW. Preparations for SRO-3 continued on a similar time-scale to NFFO

Table 21.1 summarizes progress to date in fulfilling the Renewable Energy Obligations.

21.2.2 Installed Conventional Capacity

The total capacity of plant supplying the national grid is around 60 GW.

21.2.3 Plant Type

The capacity installed during 1997 consisted of 152 machines, mainly of Danish manufacture, 8 of 300 kW rated capacity, 50 of 500 kW, 90 of 600 kW and 4 of 750 kW. This is to be compared to the average rated capacity of 38 kW for all 440 machines in NFFO-1 & 2. The machines were installed as nine wind farms (2 x 2 on adjacent sites) and one single turbine.

21.2.4 Forms of Ownership

The major UK electricity generators continue to take ownership of most of the new machines. This confirms the trend that, as the reliability and performance of wind farms becomes proven, corporate investment is increasing from, in particular, the electricity generating and distribution companies. During the year, the first UK wind farm attracting community funding was commissioned. The Bay Wind community co-operative was formed in March 1996 and has so far raised sufficient funds to buy one of the five turbines at Harlock Hill in Cumbria. In many cases the operators of the wind farms continue to be the original development companies operating under contract to the owners.

21.2.5 Energy Output

For the year from January 1 to December 31, 1997 the total energy output from projects in NFFO, NI-NFFO and SRO were 461 GWh, 88 GWh and 106 GWh respectively with a national

Table 21.1 Size and Timing of the Renewable Energy Obligations.

ORDER	EFFECTIVE START DATE	NO. PROJECTS CONTRACTED	NO. PROJECTS OPERATING	CONTRACTED CAPACITY MW DNC/RATED (approx.)	INSTALLED CAPACITY MW RATED	NO. TURBINES INSTALLED
NFFO-1	1990	9	7	12.21/(28)	27.6	75
NFFO-2	1992	49	25	82.43/(192)	126.0	365
NFFO-3 (>3.7 MW)	1995	31	6	145.92/(339)	69.2	120
NFFO-3 (<3.7 MW)	1995	24	5	19.71/(46)	8.9	19
NFFO-4 (>1.8 MW)	1997	48	—	330.4/(768)	—	—
NFFO-4 (<1.8 MW)	1997	17	—	10.4/(24.2)	—	—
SRO-1	1995	20	4	45.60/(106)	51.8	92
SRO-2	1997	7	—	43.6(101.5)	—	
NI-NFFO1	1994	6	5	12.66/(29)	30	60
NI-NFFO2	1996	2	—	2.57/(6)		

total for the year of 655 GWh. It is estimated that non-NFFO turbines produced 10.7 GWh.

21.2.6 Technical Performance

The technical performance was good with high availabilities (>95%) and average load factors approaching 30% being reported from the wind farms. The wind farms in Northern Ireland and Scotland performed particularly well with load factors approaching 0.50 in some months due to the good wind regimes.

21.2.7 Operational Experience

No operational difficulties were reported although wind speeds have again been lower than would be expected from long term averages.

21.3 MANUFACTURING INDUSTRY

21.3.1 Wind Turbine Manufacturers

During 1997, WEG commissioned the first MS4 600 in mid-Wales. The turbine is a three bladed down wind machine with self-erection capability. Renewable Energy Systems continued work on the development of their 1-MW turbine.

21.3.2 Other Industries

Component Suppliers. The year was, in general, a period of consolidation for UK component suppliers against a background of a strengthening pound and a modest home market. Towers and castings manufactured in the UK continued to be supplied to foreign turbine manufacturers. The wood-composite blade manufacturer, Taywood Aerolaminates, continued to increase its business with full order books for the year.

Consultants. There is a continuing demand for consultants in site exploration, performance and financial evaluation, planning applications and environmental impact statements as successive tranches of the Renewable Energy Obligations are announced.

21.4 ECONOMICS

21.4.1 Electricity Prices

For NFFO-4 contracts (awarded in 1997, up to 15 years in duration) the capacity weighted average bid-in price of large projects (>1.8 MW) was £0.0353 / kWh (lowest £0.0311 / kWh, highest £0.0380 / kWh) while for SRO2 projects the bid-in prices averaged £0.0286 / kWh (lowest £0.0274 / kWh, highest £0.0294 / kWh). The reductions in average bid price compared to the previous tranche of contracts for NFFO4 and SRO2 were 18% and 28% respectively.

By comparison the domestic cost of electricity varies from 7 to 8.5p / kWh whilst industrial consumers can expect to pay 4.5 to 8.5p / kWh.

21.4.2 Invested Capital

On the assumption that the average installed cost of the wind plant already installed was £1000 / kW of rated power, the total invested capital is circa £313M. On the assumption that the average cost of the wind plant installed during 1997 was £800 / kW, the capital invested during the past year was circa £67.5M.

21.4.3 Turbine and Project Costs

Based on data from developers, the ex-factory cost of wind turbines available for UK projects is around £480-580 per kW of rated power. For current projects, the total project cost for wind farm developments was estimated to be about £750-850 per installed kW. A significant factor in cost fluctuations has been the variation in exchange rates.

21.5 MARKET DEVELOPMENT

21.5.1 Planning and Grid Issues

Securing planning permission has become the greatest obstacle to the development of wind energy in the UK. The British Wind Energy Associations estimate that obtaining planning permission usually takes over 2 years and costs developers more than £100,000. These time scales and costs substantially increase if the application is refused and is then appealed. Of the 20 appeals heard since the beginning of 1994 only 4 have been successful.

In the short term developers are able to find suitable connection points for their projects. However if more ambitious medium term targets are adopted then consideration will need to be given on how best to incorporate a relatively large amount of embedded generation in to the grid system..

21.5.2 Institutional Factors

Planning. The government continued to encourage local authorities to establish local structure plans which include renewable energy developments. The government is now monitoring the local authority structure plans to review how national renewable energy policies are being incorporated into local plans. The success of applications for planning permission for renewable energy projects is also being monitored.

Certification. Standards for and certification of wind turbines continue to receive attention. The UK industry with the support of the DTI continues to be increasingly involved in national and international activities in these areas, especially with the work ongoing in the European Union.

Machine Certification requirements. The only certification requirement for wind turbine installations in the UK is under the EU Machinery Directive. Standards and certification are currently being considered by the British Standards Institute as input to possible IEC recommendations.

21.5.3 Impact of Wind Turbines on the Environment

Visual intrusion. The visual impact of turbines continues to be the prime concern in the development of UK wind farms due to developers seeking the best wind speed sites on high ground which are often in sparsely populated areas of scenic beauty. It is however to be expected that visual impact would also be the main issue in landscapes of less national importance. The conflict between the environmental benefits of wind energy and loss of landscape value continues to be a major factor in obtaining planning consent for a wind farm development. As the number of wind farms increases the question of cumulative impact is also requiring more consideration.

Noise. Another concern is that of the noise generated by wind turbines, largely because of the high population density of the UK and dispersed settlement patterns. A noise working group was set up by the DTI to review recent experience, to define a framework to measure and rate noise from wind turbines and to provide indicative noise levels for best practice. Following the publication of the Noise Working Group’s guidelines in September 1996 noise has become less of an emotive issue. It is now widely accepted that, though requiring consideration at the planning stage, wind farm noise can be properly controlled and monitored according to requirements laid down in planning conditions.

Public attitudes. Public attitude continues to be a controversial subject. Despite several surveys which indicated that local support for wind farms is high, there is still widespread adverse comment in the press from both individuals and national bodies. Organized objectors groups, co-ordinated nationally, are believed to be largely responsible for the adverse press.

Radar. The development of some projects has been delayed whilst concerns from the Ministry of Defence over the effect of wind farms on radar performance are investigated.

21.5.4 Financing

Type of funding available. Finance for wind farms is obtained largely from corporate investors and banks though there is a small amount of private investment. There is no public funding available for wind farms as the premium prices from the Renewables Energy Orders are considered sufficient incentive.

Typical financial interest rates. Interest rates asked by banks are typically 1.5% above the London Inter Bank Offered Rate (LIBOR). Equity / debt ratios are typically 25 / 75, with investors requiring a post tax return on equity of typically 15% to 25%. Clearly these figures can vary considerably from project to project. Alternatively, larger companies will often finance a project themselves off the balance sheet and will expect a real rate of return of 8% to 12% dependent on the associated risk.

21.6 GOVERNMENT-SPONSORED R, D&D PROGRAMS

21.6.1 Funding Levels

Around £1.7M of the budget for DTI's Programme on New and Renewable Energy was allocated to wind energy development during 1997 compared to £2.5M in 1996.

21.6.2 Priorities

The government continued to work in a cost-shared program with industry but as the technology achieves maturity, and subject to the renewables review currently being undertaken, the trend is towards decreasing contributions from government.

21.6.3 R&D Results in 1997

With an increasing proportion of cost-shared projects, much of the program's output remains proprietary information. One project to report of generic interest was an investigation into low frequency noise and vibration from wind farms. The main conclusion of the study was that noise and vibration levels were found to comply with recommended residential criteria even on the wind turbine site itself and the acoustic signal was below accepted thresholds of perception below 20Hz.

21.6.4 Offshore

Offshore. There is continued interest by some developers in the offshore siting of turbines, prompted in part by the difficulty of finding acceptable sites onshore. Two developers were successful in obtaining support for offshore wind farms through NFFO4. Only bids for onshore wind farms have been invited for NFFO5 although it is noted that the achievement of 10% of the UK's electricity from renewables by 2010 would almost certainly require bringing forward technologies such as offshore wind energy.

21.6.5 International Collaboration

Formal international collaboration in the DTI's wind energy program is through the IEA and the European Union (EU) programmes. The DTI encourage UK contractors to participate in EU funded projects and the DTI and the EU programs are considered to be complementary. UK contractors can receive supplementary funding from the DTI where the work is relevant to the DTI program.

CHAPTER 22

UNITED STATES

22.1 GOVERNMENT PROGRAMS

The United States is supporting wind energy research and development, along with other renewable technologies, through a variety of programs conducted by the Department of Energy (DOE) and other federal government agencies. The primary federal and largest national wind energy research and development program is conducted by DOE. The legislative authority for this effort is the Energy Policy Act of 1992, that also encourages the deployment of commercial wind systems and other renewable technologies by providing financial incentives through 1999.

22.1.1 Aims and Objectives

The objective of the DOE Wind Energy Program is to establish wind energy as a regionally diversified, cost-effective power generation technology, through a coordinated research effort with industry, electric utilities, universities, and research organizations. Wind turbines and wind energy technology are developed in close cooperation with U. S. industry, for both domestic and international market applications.

22.1.2 Strategies

The DOE National Laboratories are working with industry to conduct comprehensive, broad-based research and development. New technology developed under this program is field tested, evaluated and verified in projects that are cost shared by the users. In some cases, financial incentives are provided by the federal government and some states to encourage commercial deployment of wind power plants by private industry and electric utilities.

The DOE Wind Energy Program is structured into three areas:

1. Applied Research - to develop the basic wind energy sciences and technology;
2. Turbine Research - to develop and test advanced wind turbines in various sizes from less than 10 kilowatts (kW) to more than one megawatt (MW); and
3. Co-operative Research and Testing - to support industry in concept evaluation, field testing and initial deployment of new wind energy systems and technology. R&D efforts are focused at the National Wind Technology Center, at the National Renewable Energy Laboratory, located in Golden, Colorado. Their work is designed to develop and prove new technology and to minimize the technical, economic, and institutional risks for U.S. companies deploying advanced wind energy technologies.

22.1.3 Targets

The target of the program is to reduce wind energy system cost and improve performance so wind systems can be competitive with conventional energy sources on a life-cycle basis. With the projected improvements in wind technology and the expected energy markets, it is estimated that an additional 1,000 MW of wind systems will be installed in the United States in less than five years and that U. S. industry will supply 25% of global markets by 2005.

The specific DOE goal for large-scale, grid-connected, utility-owned wind power systems, is to produce energy at a cost (in U. S. dollars) of $0.025 per kilowatt-hour (kWh) by year 2002, at good wind sites. This cost goal includes all costs for turbines, land and the balance of station for a 50 turbine wind power plant project, located near power transmission lines. A good (Class 6) wind site is assumed to have average annual wind speeds of 6.7 m / second (15 miles / hour) measured at 10 m above ground. See section 4. Economics, below for more details.

The DOE goal for the small turbine development program is to significantly reduce the cost of energy from machines with peak power ratings from 5 to 40 kW. Specific goals depend on the type of turbine and the planned operating environment and application requirements.

22.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

About 11 MW of new wind generating capacity was added in the United States in 1997 and was composed of small projects and initial increments of capacity to test new turbines prior to large scale deployment. During the year, domestic deployment occurred at a slower rate than in recent years, but international sales of U.S. built turbines increased with new projects in Europe and Asia. With the phase out of some older wind plant projects, the total installed capacity in the United States actually declined to 1743 MW by the end of 1999. However, nearly 800 MW of new projects are either under construction or planned to be built in the next several years. Existing capacity and planned projects are shown in Figure 22.1.

The estimated energy production from the installed wind capacity in the United States was about 3.7 terrawatt-hours during 1997.

Wind energy deployment in the United States is continuing to expand at different sites and in new applications. A number of commercial projects have been contracted in the Midwestern states. There are 142 MW of new wind projects currently under construction or planned for 1998 in Minnesota and Iowa. Zond Energy Systems Company, a subsidiary of Enron Wind Corporation, is negotiating contracts for more than 400 MW to be installed in the United States over the next few years. One planned 112.5 MW project to be located in Iowa, will be the largest single wind power plant in the world. Other companies are negotiating smaller projects in the states of Colorado, Texas, Washington and Wyoming.

New projects are also being developed in smaller scale utility applications. In the initial phase of a new project, three Atlantic Orient Corporation (AOC), AOC 15-50, 50-kW wind turbines were commissioned in the isolated village of Kotzebue on the western coast of Alaska just north of the Arctic Circle (Figure 22.2). This project is supported by the DOE and the National Renewable Energy Laboratory. It is also part of the Turbine Verification Program, a joint program between DOE and the Electric Power Research Institute (EPRI), which is intended to reduce the risk to utilities of deploying unfamiliar technology and to confirm the machines’ performance and reliability in new operating environments. Seven additional machines are planned to be added to the cluster in 1998 to complete the first phase of an eventual 2-MW project.

In another Alaska project, DOE is supporting installation of three 50-kW AOC turbines in a high penetration wind / hybrid project for the village of Wales located on the Bering Strait. The Wales project combines wind, battery storage and diesel-electric generator units in a hybrid power system operated in a manner that allows the diesels to be shut down when the wind is sufficient to carry the village load. Installation of the Wales system is expected to begin in the summer of 1998.

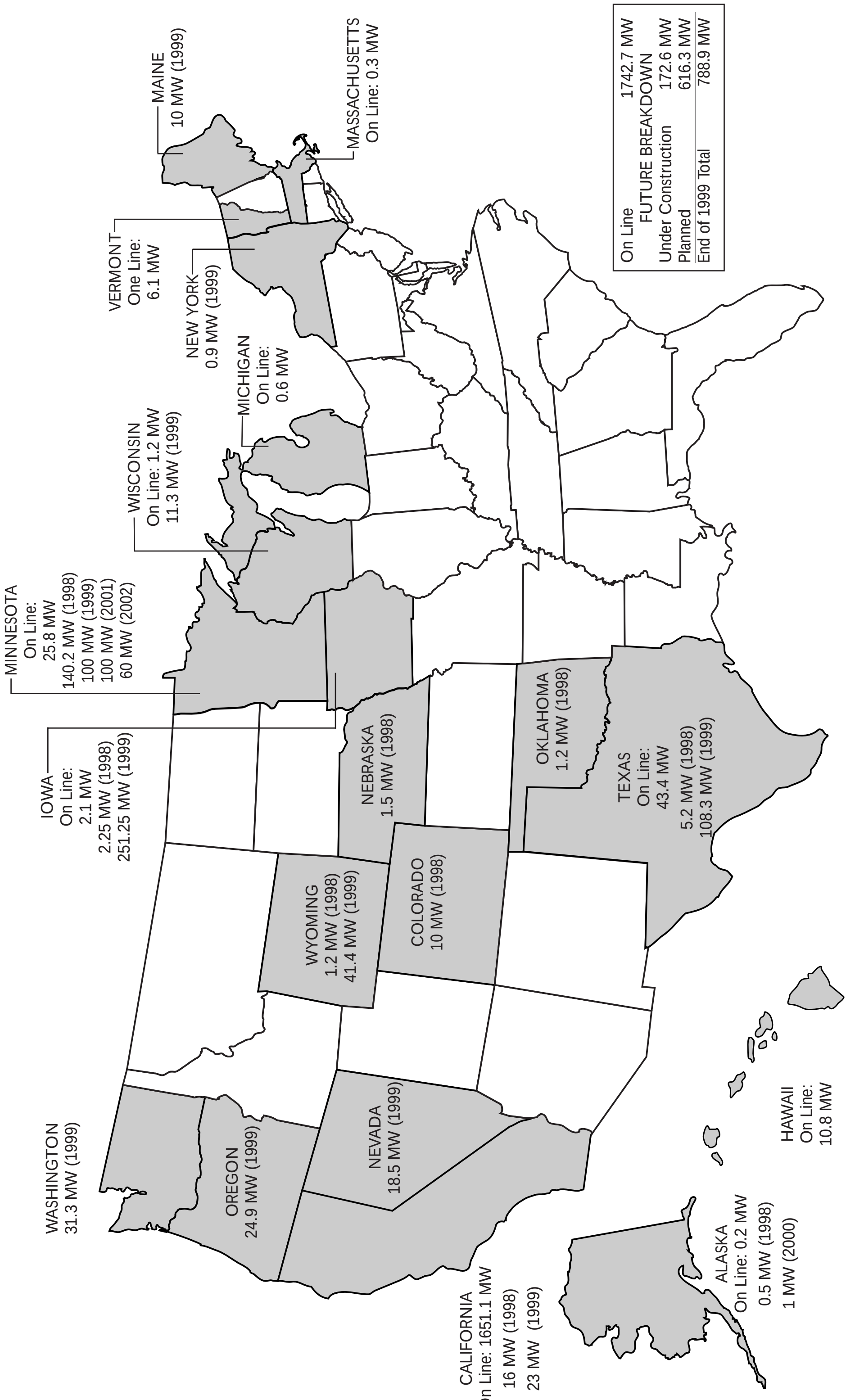


Figure 22.1 Map of grid-connected wind power plants planned, under construction and operating in the United States at the end of 1997.

Figure 22.2 One of three 50-kW AOC 15/50 turbines in artic wind power plant in Kotzebue, Alaska.

22.3 MANUFACTURING INDUSTRY

About a dozen U.S. electrical and mechanical turbine manufacturers have produced over $3.5 billion in goods and services since 1980. The U. S. wind turbine manufacturing industry is consolidating however. Slow domestic sales have hurt some companies, but it is expected that the companies that emerge will be stronger with the potential to capture a larger market share. Many of these firms are developing new turbines for both domestic and international markets, including windfarm projects being developed in China, Germany, Ireland, Italy, Spain, and the United Kingdom and small turbine applications in Chile, China, Indonesia, Russia and many other countries. Some of these projects were installed during 1997. Others will be built in 1998 and 1999.

During 1997, Zond Energy Systems, Inc. received Type Certification for their 550-kW, Z-40 turbine. This is the first turbine developed with DOE support that has received International certification. Several other U. S. turbine manufacturers are proceeding to obtain certification , to allow export of their turbines to countries with mandatory requirements. For turbine installations in the United States, certification is not required because the wind turbines developed in the United States are designed to meet or exceed current design standards for safety, reliability and maintainability. Some manufacturers offer commercial warranties that are similar to other industrial equipment. Under this free market approach, more than 17,000 wind turbines have been successfully deployed domestically and additional units overseas.

22.4 ECONOMICS

The DOE Wind Energy Program has been very successful in reducing the levelized cost of wind generated electricity from $0.35/kWh in 1980, to $.07/kWh in 1990, and to less than $0.05/kWh today at sites with moderate winds, 5.8 m/s annual average (13 mph), measured at 10 m above ground. At current costs, and in selected markets, wind energy can compete with conventional energy sources on a life-cycle basis. Ultimately, wind energy is expected to compete favorably with gas and coal-fired power plants, that dominate the generation mix in the Midwestern United States where the majority of the best wind resources are located. To tap this vast resource base, and to allow wind to compete in an era of utility restructuring that emphasizes low cost and independent power projects, significant improvements to the technology are still needed to reduce costs and improve performance.

The basis for these estimates and the projected evolution of wind and other renewable energy systems are discussed in the *Renewable Energy Technology Characterizations*, developed and published under a joint project by DOE and EPRI. Projected wind system costs and performance from the study are summarized in Table 22.1. Projections for other renewable technologies are included in the report which is available on the DOE web page at: *www.eren.DOE.gov/*.

22.5 MARKET DEVELOPMENT

The market in the United States is evolving and issues that were slowing deployment are being resolved, thus clearing the way for significant expansion. One issue in electric industry restructuring, is that opening retail power markets to competition often includes special provisions encouraging markets for green electric power, defined as electricity produced in part from renewable sources. Surveys indicate that U.S. consumers appear ready to pay extra for green electricity and some states are prepared to pay subsidies. In the State of California most of the green products carry a price premium of between 10% and 20% (up to $0.01 to $0.02 / kWh). To compensate, the state offers a $0.015 / kWh rebate to consumers who buy from renewable energy generating projects located in the state.

In California, beginning in March 1998, electricity consumers will be able to select their electricity supplier. As a result, Enron Wind Corporation has announced plans to build a 39-MW wind plant to supply some of this green power for Southern California. Companies that want to sell green electricity can obtain independent private certification from the Center for Resource Solutions in San Francisco, that their electricity consists of at least 50% renewable energy content. Six green power marketers, including Enron, have already been certified early in 1998. This procedure will assist consumers in choosing their electricity supplier.

Green Mountain Energy Resources, a Burlington, Vermont-based power marketing company, is preparing three new electricity products for the California market, designed to meet customer desires for cleaner electric power. These products feature energy generated from renewable sources such as hydro-power, geothermal, biomass and wind. In particular, Green Mountain Energy Resources is offering a product called “Wind for the Future.” If consumers purchase this blend of electricity, it will trigger the construction of new wind turbines. The company has two additional products. One is called “75% Renewable Power,” and the other is called “Water Power.” For more information contact the Green Mountain Energy Resources web site: *www.choosewisely.com*.

The State of Massachusetts is using a somewhat different approach to increase the renewable energy content above the 6% to 7% of electricity sold today. They have developed a portfolio standard which will require an increase in renewable energy sources. According to the standard, new renewables must equal 1% of electricity sales beginning in year 2003. This must increase by another 0.5% annually through 2009 and 1% annually, thereafter, until a date determined by the state energy office. In a separate pilot program run by the Massachusetts Electric Company, 31% of residential customers chose green power options, where the electricity suppliers offered a program with a wide range of incentives. The incentives allocated the green part of the power bill to environmental programs including: supporting a portfolio of renewable energy sources, donations to environmental groups, renewable system installations, retirement of air emission credits, energy efficiency products and services, and even a raffle for an electric car.

There are several categories of financial incentives available from the Federal government for wind power and other renewable energy developers. The two primary incentives that are specific to renewable technologies are contained in the Energy Policy Act of 1992. One section introduced a $0.015/kWh production incentive for electricity sold to an unrelated party from eligible wind and closed-loop biomass facilities. The eligibility period is currently January 1, 1994, through June 30, 1999, and there are proposals to extend this for five more years until 2004. For investor-owned (tax paying) utilities, the production incentive is taken as a tax credit. For nonprofit electricity generators that are tax exempt, such as municipal or co-operative electric agencies, the Renewable Energy Production Incentive (REPI) is available as an incentive payment from DOE but is subject to annual funding by Congress. Incentive payments made during 1997, for energy produced during 1996 by wind, solar and biomass plants, totaled $2.5 million. Of this total wind projects received payments totaling more than $167,000 for the year.

22.6 GOVERNMENT-SPONSORED PROGRAMS

The DOE Wind Energy Program is structured to develop new technology and assist utilities and the U.S. industry in introducing wind into new markets and

Table 22.1 Advanced Wind Turbines in Wind Farms - Performance and Cost Projections 1997 through 2005. Source: EPRI/DOE Renewable Energy Technology Characterizations, Dec. 1997

INSTALLATION CHARACTERISTICS	BASE CASE 1997	+/- %(1)	2000	+/- %	2005	+/- %
Turbine Size (kW)	500		750		1000	
Hub Height (m)	40		60		70	
Rotor Diameter (m)	38		46		55	
Capacity Factor %(2)		+5/-15		+10/-20		+10/-25
Class 4 Wind, 5.8 m/s (13 mph)	26.5		30.2		35.1	
Class 6 Wind, 6.7 m/s (15 mph)	35.5		40.4		45.3	
Availability (%)	98	+1/-2	98	+1/-2	98	+1/-2
Estimated Installed Cost ($/kW)(3)	1000	+10/-20	750		720	
Annual O&M Cost ($/kWh)	0.01	+20/-30	0.008	+20/-30	0.005	+20/-30
Levelized Cost of Energy(4)					(5)	
Class 4 Wind ($/kWh)	6.4		4.3			
Class 6 Wind ($/kWh)	5.0		3.4			

1. The +/- range bounds a projected emerging technology and market uncertainty envelope.
2. Average annual wind speeds measured at standard height of 10 m. Wind speeds at turbine hub height are assumed to be higher, using 1/7 power wind shear.
3. Includes Balance of Station (BOS) costs including: foundations, control/electrical hardware, site preparation, substations, collection and transmission lines, O&M facilities, wind measurement equipment and administrative costs; BOS ranges from 25% to 33% of project cost.
4. Generating Company (GenCo) is assumed to have market based rate of return and capital structure. GenCo case assumes 35% of debt financed at 7.5% annual return and 65% of debt at 13% return.
5. DOE cost goal of USD 0.025/kWh is met in year 2002 with assumptions of most favorable project financing, with Municipal Utility ownership and good wind sites. Financing for Municipal Utility case assumes 100% debt at 5.5% return and that the public utility does not pay taxes. Technology advances by year 2005 should enable USD 0.025/kWh cost of energy goal to be met with GenCo financing at excellent (Class 6) wind sites.

applications. The DOE Program works with industry on activities including: applied research, turbine research, and co-operative research and testing. The program funding was $28.6 million in Fiscal Year 1997 and is $32.5 million in 1998.

The Wind Program's R&D activities are focused at the NREL's NWTC, located on a 280-acre site near Golden, Colorado with supporting research at Sandia National Laboratories in Albuquerque, New Mexico. The NWTC conducts a wide range of wind energy research, component development, and testing to complete system verification. The NWTC includes several test turbines for the study of unsteady-aerodynamics and variable-speed operation, a turbine blade structural test facility, an industrial user facility and a new hybrid systems test bed. The hybrid power system test capability, integrates wind turbines with other renewable power systems and two 60 kW diesels in simulated village power applications. Construction was completed in 1997 of a 600-kW Advanced Research Turbine (Figure 22.3) for full scale component and system testing. The NWTC has become one of the most comprehensive wind energy research facilities in the world.

22.6.1 Applied Research Program

Applied research continues to ensure that fundamental analysis and design tools are available for industry to perform detailed designs of future advanced wind turbines. Research includes 3-D computer models for aerodynamic performance, structural dynamics, and yaw dynamics. Key research activities support the wind industry's needs for turbines, components, and subsystems with better and more innovative designs, but which could yield major improvements in turbine performance, reliability, and cost. Projects include the 10 m diameter unsteady aerodynamics research test bed, wind characterization for the Great Plains, research on avian issues, aerodynamics, structural dynamics, materials fatigue properties, and power subsystems. A new 3-MW dynamometer facility is being built to allow full-scale, full-power testing of new turbine drive and generator systems.

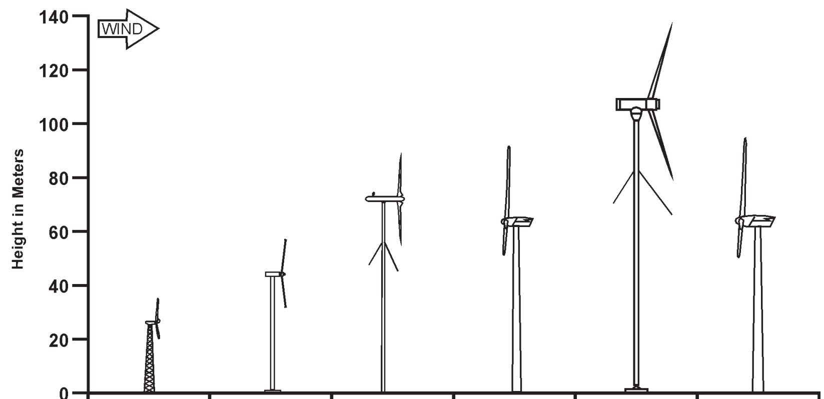
22.6.2 Turbine Research Program

The development of technologically advanced wind turbines is one of DOE and industry's highest priorities. The Program includes development of a variety of turbines in sizes from 8 kW to over one MW. A dual-path technology development approach is taken, supporting both near-term and next-generation system development. This effort has supported the development, fabrication, and field testing of several new utility-scale turbines (See Figure 22.4). The near-term cost-of-energy goal of $0.05 / kWh or less at 5.8 m / s sites by the mid-1990s has been met and one of the resulting machines, the Zond 550 kW Z-40 turbine, is now available commercially. The other near-term machines, still being field tested, will help bridge the gap between earlier first generation technology and the next-generation of utility-grade wind turbines under development.

Next-generation turbine development will employ advanced technology and innovative designs to reach the target levelized costs of electricity of $0.04 / kWh or less (at 5.8 m / s wind sites) and $0.025 / kWh (at 6.7 m / s) around year 2002. These machines will compete directly for bulk electric power markets without the need for subsidies. In 1997, two subcontracts were signed with industry to develop next-generation turbines. Zond Energy Systems, Incorporated in Tehachapi, California (a subsidiary of Enron Wind Corp.), and The Wind Turbine Company in Belleview, Washington, signed subcontracts with the DOE / NREL to design and test a new generation of wind turbines,

Figure 22.3. 600-kW Advanced Research Turbine located at the National Wind Technology Center near Golden, Colorado.

each about one MW in size, that will use the most recent technology in all aspects of wind turbine engineering. Each company will cost-share 30% of their $20 million contract. Innovative subsystem development activities, currently underway, also support the next-generation path by exploring advanced variable speed generators, blade and rotor manufacturing, and control systems.



	AOC 15-50	AWT 27	Cannon/ Wind Eagle	ZOND Z-50	Wind Turbine Company WTC-1000	ZOND Z-56
Rated Power (kW)	50	275	300	750	1000	1000
Rotor Diameter(m)	15	27	29	50	54	56
Number of Blades	3	2	2	3	2	3
First Prototype Year	1993	1996	1997	1998	1999	1999
	NEAR TERM				NEXT GENERATION	

Figure 22.4 Advanced utility-scale turbines under development.

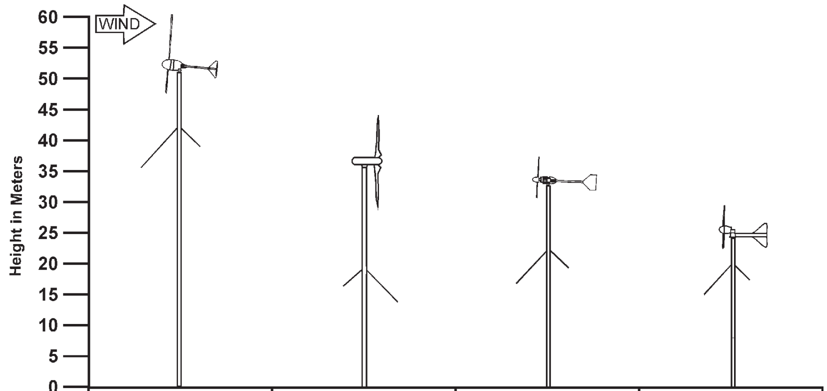
Contracts were recently awarded to four companies to develop small turbines for both grid-connected and off-grid power generation. Following an open competition, the companies selected to develop the new machines were: Bergey Windpower from Norman, Oklahoma for a 40-kW turbine; Cannon Energy Corporation from Tehachapi, California a 30-kW turbine; WindLite Company from Mountain View, California an 8-kW turbine; and World Power Technologies, Inc. from Duluth, Minnesota for a 14-kW turbine. General characteristics or the small turbines under development are shown in Figure 22.5.

Working with EPRI, DOE initiated a joint Utility Wind Turbine Verification Program to evaluate the performance of new wind turbines and to introduce wind energy technology to utilities. DOE and EPRI believe that experience operating a small wind power plant, will allow utilities to make informed decisions about adding new wind generation in the future. Under this program, Green Mountain Power Corporation from Burlington, Vermont and Central and South West Services, Inc., of Dallas, Texas, each built new cost-shared 6-MW wind power plants.

During 1997, DOE and EPRI initiated a new Turbine Verification Program activity called the Distributed Wind Generation Project, targeted at utilities or independent power producers interested in building smaller, dispersed wind generation facilities connected directly to a distribution line. As a result, additional Turbine Verification Projects were selected for installation at seven sites. (See Table 22.2.) The sites selected will help utilities reduce the risk of introducing a new and unfamiliar technology and to evaluate costs and benefits of utility-controlled wind power generation built at dispersed locations.

22.6.3 Co-operative Research and Testing Program

DOE has sponsored several efforts aimed at encouraging the deployment of wind energy technology. One project is located



	Bergey Windpower	Cannon/Wind Eagle	WindLite	World Power Technnology
Rated Power (kW)	40	30	8	14
Rotor Diameter(m)	16	14	7	7
Number of Blades	3	2	3	3
First Prototype Year	2000	1999	1998	1999

Figure 22.5 Advanced small wind turbines under development.

in northwestern Iowa, and the other in southwestern Minnesota. Waverly Light and Power plans to install two Zond Z-46 turbines in Iowa. Zond Energy Systems plans to develop a 11.5-MW wind power plant near Lake Benton, Minnesota, in cooperation with Northern States Power Company.

Deployment of wind systems in off-grid applications is supported by the new hybrid power test bed facility at the NWTC. Hybrid power systems, combining wind turbines with photovoltaic arrays, battery storage and diesel generators can be tested with simulated village loads. Researchers can evaluate system interactions during normal and simulated fault conditions.

Another part of the NWTC that began full scale operation was the Industrial User Facility. This new 930 square meter building is used by both industry and laboratory staff working side by side on wind turbine blade and component tests and research. Turbine blades up to 26 m long can be subjected to extreme structural loads and to high cycle fatigue loading on test stands on the new building. It has proven useful for certification testing and problem solving on new blade designs.

International standards and certification testing capabilities are areas of increasing emphasis. Efforts are continuing at the NWTC, to achieve accreditation for the laboratory facilities and operating procedures under International Standards Organization (ISO)Guide 25. Testing of commercial turbines is already being done by the NWTC and the results have been used by several turbine manufacturers to obtain certifications needed for some overseas markets. International standards and recommended practices, are being developed through work with U. S. industry and international organizations including the International Electrotechnical Commission and the International Energy Agency.

Analytical studies and model development are part of this program. These studies include development methods for evaluating the economic value of adding wind systems to an existing utility and integrating these models into

Table 22.2 DOE/EPRI Turbine Verification Program Distributed Generation Projects.

UTILITY	LOCATION	TURBINES/TOTAL CAPACITY	PLANNED DATE ONLINE
City of Brownfield	Brownfield, Texas	6 turbines/totaling 4.5 MW	1999
Central and South West Services	Oklahoma	4 Cannon Wind Eagle/1.2 MW	TBD*
Cedar Falls Utilities	Algona, Iowa	3 Zond Z-50/2.3 MW	1998
Nebraska Public Power District	Springview, Nebraska	2 Zond Z-48/1.5 MW	1998
Niagara Mohawk Power Company	Harrisburg, New York	3 Cannon Wind Eagle/900 kW	TBD*
Kotzebue Electric Association	Kotzebue, Alaska	10 AOC 15-50/500 kW Phase 2 TBD/1.5 MW	1998 TBD*
Wisconsin Public Service Corporation	Glenmore, Wisconsin	2 Tacke TW-660e/1.2 MW	1998

*To be determined.

commercially available utility operational planning models. Wind measurement and data analysis are done along with utilities that are planning to deploy wind power plants. This element is called the Utility Wind Resource Assessment Program

22.6.4 International Programs

The DOE Wind Program provides technical assistance to governments and utilities in countries planning wind projects in Central and South America, Asia, Africa and elsewhere. An example is a bilateral agreement signed with the Ministry of Electric Power in China that will allow the exchange of scientists and assistance in planning large scale grid-connected and village power wind projects. A pilot project involving the installation of several 10-kW turbines in an isolated community in China is planned for 1998. Other projects are funded in part by DOE and the United States Environmental Protection Agency and the Agency for International Development. These activities include assessing opportunities for renewables' use overseas, supporting wind/photovoltaic hybrid pilot projects and feasibility studies, increasing access to project financing and supporting renewable energy education efforts. Small turbines have been installed in village power pilot projects in Brazil, Chile, Indonesia, Mexico, Philippines and Russia. Support for windfarm projects overseas is done through technical assistance to interested countries and to the regional and multilateral banks.

APPENDIX A

The 40th Executive Committee meeting in Rotorua, New Zealand, on November 26/27, 1997.

APPENDIX B

IEA R&D EXECUTIVE COMMITTEE 1997
M = Member A = Alternate Member

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IEA WIND ENERGY ANNUAL REPORT 1997

Wind energy stands out as one of the most promising renewable energy sources in the near term. The deployment of wind energy is promoted by national programs for advanced technology research and market incentives in many countries.

Parties from 17 countries and the European Commission collaborate in wind energy research and development under the auspices of the International Energy Agency. The program includes joint research projects and information exchange on wind systems development and deployment.

The report reviews the progress of the joint projects during 1997 and highlights the national wind energy activities in the member countries.

Wind system sales are expanding around the world and now total USD 1.5 billion annually. This includes deployment in non-OECD countries, where demand for wind systems is expected to grow significantly in the future.

There has been a trend towards larger commercial turbines (now up to 500-750 kW, corresponding to rotor diameters of up to 40-45 m). Prototype megawatt-sized turbines (up to 3 MW) are in operation in nine member countries.

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